Table 1. Project history of the Dynamic Underground Stripping project LLNL gasoline spill site cleanup.

Phase	Dates	Objectives	Accomplishments
Vacuum Extraction, Vadose Zone EM 40 Operations	9/88 to 12/91	> Extract vadose gasoline contamination. > Evaluate extraction effectiveness.	> Pilot Test permitting received. > 2000 gallons removed > Biological activity confirmed
Clean Site Engineering Test EM 50	2/91 to 9/91	> Demonstrate establishment of steam zone below water table. > Evaluate and optimize monitoring, imaging systems. > Optimize resistance heating electrode design. > Evaluate personnel and environmental safety.	> 10,000 yd^3 steam zone established below water table with no steam rise. > ERT, thermal logging, and tiltmeters demonstrated, chosen for gas pad use. > Individual electrode capacity raised from 20 kW to 60 kW. > Safe procedures established for personnel; no detrimental environmental effects .
Electrical Pre-Heat EM50 operations, EM 40 Treatment Facility F construction	11/92 to 1/93	> Raise temperature of clay/silt layers 20°C so conductivity always above steam-temperature gravel zones. > Test electrical safety at high current in industrial area. > Optimize electrical heating methods.	> Clay pre-heating accomplished. > Maximum heating to 70°C in clay layer. > Safety measures and procedures adequate. > 850 k W continuous power achieved. > Nighttime operations with daylight construction of treatment facility.
1st Steam Pass Joint EM40/EM50 operations	2/93 to 3/93	> Heat target zones to steam temperature. > Optimize monitoring/control methods. > Evaluate treatment procedures and facility. > Quantify possible deleterious effects (such as contaminant spreading). > Demonstrate safe handling of steam and hot gasoline effluent.	> Upper and Lower steam zones heated to boiling point. > ERT established as control system with 12 hr turnaround on 10 planes/day. > Non-contact thermal logger demonstrated with no hysteresis, 100°C/2 ft gradients. > Gasoline found to be mainly recovered in vapor phase, greatly exceeding capacity. No liquid phase free-product recovered. > No spreading of contaminant to outer monitoring wells/ > Safe handling of steam and hot gasoline. > 1700 gallons gasoline removed.

Table 1. (Continued.)

2nd Steam Pass **Joint EM40/EM50 operations**	5/93 to 7/93	> Operate re-designed vapor treatment system with 10x capacity of first pass. > Optimize steaming/recovery technique to maximize vacuum recovery. > Heat zones which were insufficiently heated in first pass. > Accurately measure gasoline flux in vapor and condensate paths, reduce uncertainty in total recovery rate, continuously monitor gasoline flux.	> 100,000 yd^3 heated to boiling point. > Recovery rates in excess of 250 gal/day achieved. > Tiltmeters used for imaging of horizontal extent of steam zones from individual wells. > Most cool zones from 1st pass fully heated to steam temperature one "cold spot" remained at 80°C). > Fluxes measured to ± 10 % accuracy, continuous monitoring systems demonstrated. > 4600 gallons gasoline removed.
Post-Test Drill-Back Characterization **EM 50**	7/93 to 9/93	> Measure soil concentration changes along six-hole cross-section > Ascertain from soil concentrations whether spreading had occurred (outside original contamination) > Evaluate process effectiveness. > Examine possible changes to soil. > Examine effects on existing microbial gasoline-degrading ecosystem.	> Soil concentrations reduced dramatically. > No spreading of contaminant; ony inward motion seen. > Vadose zone completely clean (< 1ppm) > Saturated zone contaminant remained around extraction cluster only. > No significant soil changes. > Active microbial ecosystems at all locations and soil temperatures up to 90°C, makeup varies by soil temperature.
Accelerated Recovery and Validation (ARV) **EM 40 Operations**	10/93 to 1/94	> Remove remaining free product, especially in cool zone. > Make use of existing heat and high extraction rates to continue removal. > Electrically heat clay/silt zones to enhance removal. > Test sparging, injection well extraction.	> Remaining free-product gasoline removed (1000 gallons). > Ground water concentrations of 5 of 6 regulated compounds reduced to MCL. > Benzene down to 100 ppb in ground water. > Sparging monitored with noble-gas tracers. > Electrical heating maintained site soil temperatures during extraction.